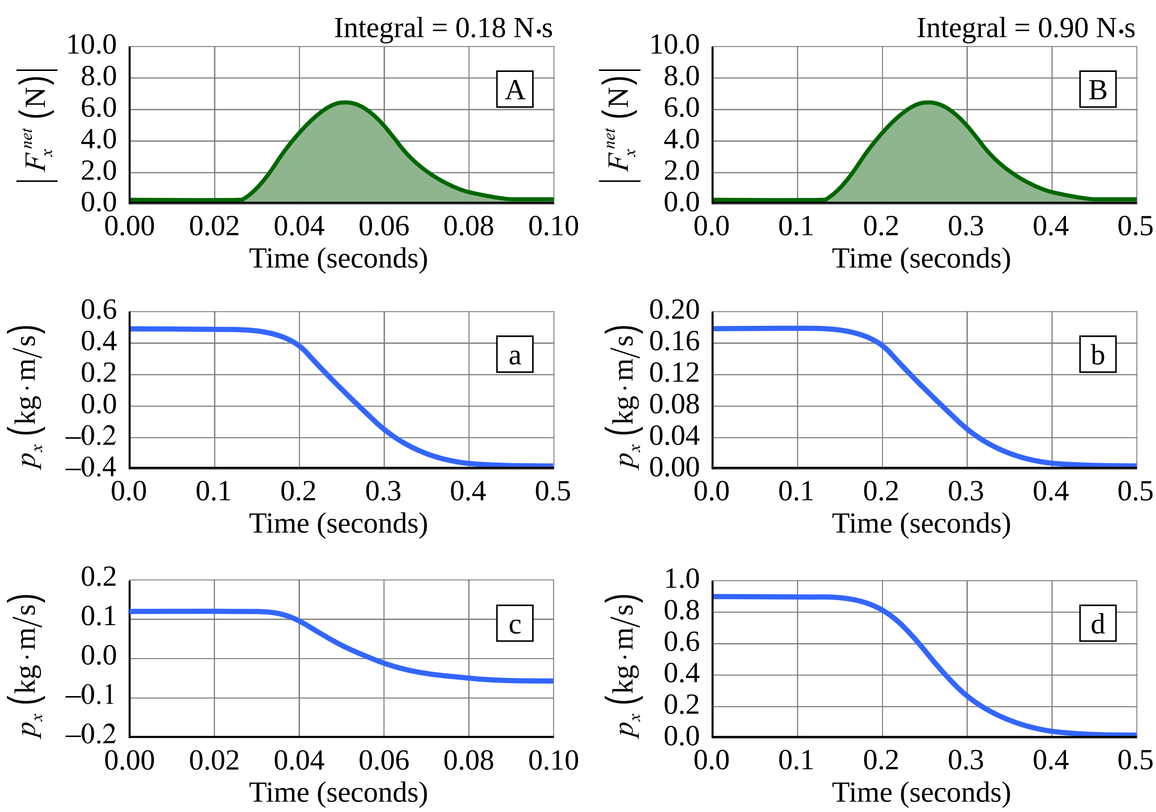
Unit 9 Homework Problems

To get credit for the homework problems, you must include all of the following:

1. All equations must be solved in symbol form before substituting in any numbers.
2. All numbers substituted into the equations must have the correct units and number of significant figures, and the correct vector notation (where appropriate).
3. All final numerical answers must have the correct units, correct number of significant figures, and correct vector notation (where appropriate),
4. All problems should include a reference to the Activity Guide activity or activities that are related to the problem, a discussion of ***how*** the activity is related, and a discussion of the ***concepts*** that were learned in the activity.

Problems 9-1 and 9-2 refer to the graphs that follow. These graphs depict two force magnitude vs. time curves and several related momentum vs. time graphs. They describe a low-friction cart traveling along an *x*-axis with a force sensor attached to it. The cart-force sensor system has a mass of 0.50 kg. The cart undergoes a series of collisions. It collides with a wall with a hard wall, and with a wall that is padded with soft foam. Sometimes there is a small clay blob on the wall causing the cart-force sensor system to stick to the wall after the collision.



9-1) **Finding Momentum Change and Impulse:** (a) What is the approximate momentum change associated with graph a? With graph d? Determine this change by taking approximate readings from the graphs. Show your calculations using *both* simple symbol-based equations *and* the numbers you substituted into them.

(b) Which of the two impulse curves, A or B, might lead to the momentum change depicted in graph a? In graph d? Explain the reasons for your answer.

(c) Suppose the forces on the cart-force sensor system were described by graph A. What would its velocity change be?

9-2) **Relating Impulse Curves to Collisions:** Suppose you collected F_x vs. *t* and p_x vs. *t* data for a series of collisions for an important project report and then you lost your notes. Fortunately, you still had your graphs on your computer. You don't know which graph corresponds to which collision, but you are able to reconstruct some of your work by asking and answering the following questions:

(a) Which F_x vs. *t* graph, A or B, probably resulted from collisions between the cart-force sensor system and a soft, padded wall? Which one probably resulted from collisions between the force sensor and a hard wall? Explain in words the reasons for your answers.

(b) Which p_x vs. *t* graphs probably resulted from collisions between the cart-force sensor system and a padded wall? Which ones probably resulted from collisions between the cart-force sensor system and a hard wall? Explain the reasons for your answers. **Hint**: There may be more than one graph for each type of collision.

(c) Which p_x vs. *t* graphs correspond to a situation in which the cart bounces back? Which p_x vs. *t* graphs correspond to a situation in which you placed a small clay blob on the force sensor hook so that the cart sticks to the wall that it collides with? Explain the reasons for your answers. **Hint**: There may be more than one graph for each type of collision.

The next three problems, 9-3 through 9-5, involve an essentially one-dimensional collision between two pucks of essentially equal mass on an air table as shown in the *pru011.mov* movie. The pucks are floating on a pad of air, so they have only a small kinetic friction associated with their motion. Thus, the pucks form an approximately closed system and the only net forces experiences by either of the pucks are the mutual interaction (normal) forces between them during their collision.

When you collect data for this movie in problems 9-4 and 9-5, you will first want to save both the movie *pru011.mov* and the file *pru011.cmbl.* The *pru011.cmbl* file opens the movie and configures Logger Pro so it is scaled, and so that the *x*-axis of the coordinate system has been rotated by 50^{o} to line up with the direction of motion of the pucks.

9-3) *If the two-puck system is isolated, what will their combined final velocity be after their collision?* In this problem you should use the Law of Conservation of Momentum derived from Newton's Second and Third Laws to predict the final velocity of the two pucks. *Do not collect data yet!*

(a) A puck of mass 51.4g is moving along the *x*-axis at a velocity of $\vec{v} = \left(-1.3\ \text{m/s}\right)\hat{x}$. It collides with a stationary puck of mass 51.5 g and sticks to it. The pucks now move off together. What do you predict is the magnitude and direction of the combined momentum of the two pucks after their collision?

(b) If there is a small kinetic friction force associated with the motion of the pucks and perhaps a bit of rubbing with the air table at the moment the pucks collide, do you expect the actual final momentum of the pucks to be greater than, less than, or equal to the value you predicted in part (a)?

9-4) *Is momentum conserved in the collision between the two pucks?* Physicists have reason to believe that in an isolated system momentum is always conserved, and that if an experiment doesn't show that conservation then the system under study isn't isolated. In this problem you are to analyze the two-puck collision in the movie *pru011.mov*.

(a) Open the file entitled *pru011.cmbl* that you previously saved with the *pru011.mov* movie. Use Logger Pro and Excel with modeling to find the initial velocity of the moving puck and final velocity of the ***combined*** pucks after collision.

(b) Compare the magnitude and direction of the velocity of the two-puck system to the velocity you predicted in problem 9-3. **Note**: Your instructor found that momentum is almost conserved; if you are not getting this result, you may have a problem with your calculations in problem 9-3) or with your Logger Pro and Excel analysis!

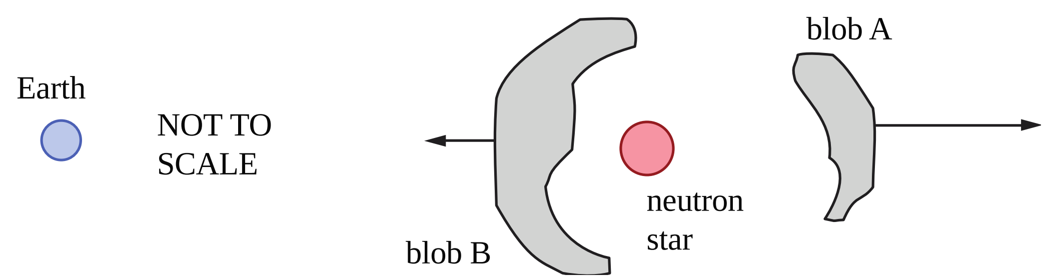
(c) If there is a small discrepancy then we believe that some other object is carrying the missing momentum. Assuming that the law of conservation of momentum always holds, discuss whether any momentum appears to be missing and what object might be carrying the missing momentum.

9-5) *How does the center of mass of a system of two equal masses move?* Open the file entitled *pru011.cmbl* that you previously saved with the *pru011.mov* movie.

(a) Collect data for the position average between the two pucks before and after the collision. (In the special case of equal masses, the position average is equal to the *center of mass*). Transfer your data to a spreadsheet and plot the average position (that is the center of mass of the two-puck system) as a function of time (x_{com} vs. t). Include a printout of the average position vs. time data and graph. Examine the graph. Is the momentum of the average position of the pucks (in other words the center of mass) a constant before and after the collision? During the collision? What is the experimental evidence to support your findings?

(b) If the resulting graph is a straight line (hint: it should be), you can use modeling to determine the equation relating x_{com} vs. t. Based on the equation you determined, what is the magnitude of the momentum of the center of mass (average position) of the pucks?

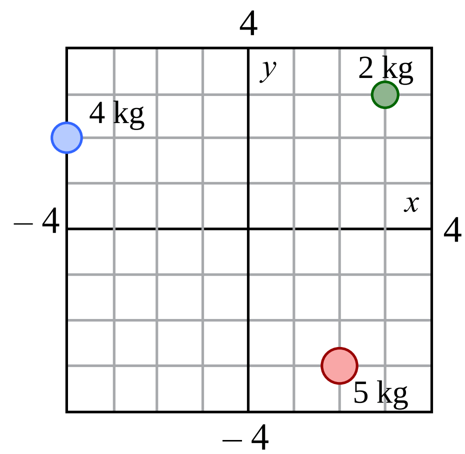
9-6) A Supernova is a massive star that blows up, sending part of its mass off into space and leaving behind a small, dense neutron star. An asymmetry was detected in the explosion of the Supernova 1987A. Assume that the Supernova was essentially at rest relative to the earth before it explodes. As a result of the explosion, a blob of material having a mass of $m_A = 2.62 \times 10^{30}\,\text{kg}$ has been ejected away from earth at a speed of $1.95 \times 10^6\,\text{m/s}$, while the rest of the ejected material having a mass of $m_B = 7.28 \times 10^{30}\,\text{kg}$ is moving toward the earth at a rate of about $2.00 \times 10^5\,\text{m/s}$. After the Supernova explodes and the two fragments are moving off in opposite directions, a third fragment in the form of a neutron star of $m_{NS} = 2.97 \times 10^{30}\,\text{kg}$ is also present.



(a) Do you expect momentum to be conserved in the explosion? Explain

(b) At what speed and direction should the neutron star be moving relative to the earth?

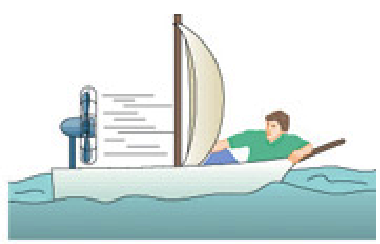
9-7) Three objects located in the *x-y* plane have the following coordinates: a 5.0-kg object has coordinates given by (+2.0, – 3.0) m; a 4.0-kg object has coordinates (– 4.0, +2.0) m; a 2.0 kg object has coordinates (+3.0, +3.0) m. Find the coordinates of the center of mass to two significant figures.



9-8) **The Center of Mass of the Sun-Earth System:** The mass of the Sun is 329,390 Earth masses and the mean distance from the center of the Sun to the center of the Earth is 1.496 x 10^8 km. Treating the Earth and Sun as particles, with each mass concentrated at the respective geometric center, how far from the center of the Sun is the center of mass of the Earth-Sun system? Compare this distance with the mean radius of the Sun (6.960 x 10^5 km).

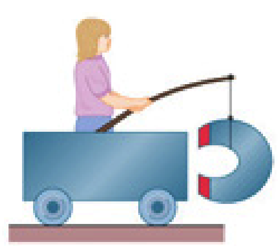
9-9) *Self Propulsion: Applications of Newton's Law and Momentum Conservation.* For time immemorial people have been cooking up schemes for low energy propulsion. Of course, we believe that whatever is designed better be compatible with Newton's Laws and the Law of Conservation of Momentum (which is a consequence of Newton's Second and Third Laws). Several schemes are shown below. Which ones do you think will work? Answer questions detailed in (a) through (d) by referring to the diagrams that follow and do a sketch of each situation to accompany your answer.

(a) A lazy fisherman turns on a battery-operated fan and blows air onto the sail of his boat. Will he go anywhere? If he moves, what will his direction be? Explain.



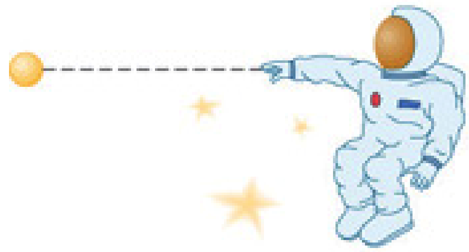
(a)

(b) A clever child is dangling a large magnet out in front of her wagon. It attracts a smaller magnet that she has attached to the front of her cart. Will she go anywhere? If she moves what will her direction be? Explain.



(b)

(c) An astronaut is floating in outer space and wants to move backwards. She tosses a ball out in front of her. Will she go anywhere? If she moves, what will her direction be? Explain.



(c)

(d) A college student on roller blade skates has a carbon dioxide container strapped to her back. The carbon dioxide jets out behind her under pressure. Will she go anywhere? If she moves what will her direction be? Explain.

(d)

9-10) Predicting A 2D Collision: You are working for the Defender's of Wildlife on the protection of the bald eagle, an endangered species. Aardman Animations has agreed to help your cause by producing an animated movie about the bald eagle. You have set up a dramatic scene in which a young rabbit is frightened by the shadow of the eagle and starts bounding toward the east at 30 m/s as the Eagle swoops down vertically at a speed of 15 m/s. A moment before the eagle contacts the rabbit, it (the rabbit) leaps off a cliff and is captured in mid-air. The animators want to know how to portray what happens just after the capture. If the eagle has a mass of 2.5 kg and the rabbit has a mass of 0.8 kg what is the *velocity* of the eagle with the rabbit in its talons just after the capture? **Hint:** You need to specify the speed and direction of the eagle-rabbit system. Include a diagram of the situation before and after capture with vectors showing the velocities.